Environmental Show of the South, April 2016

GEOMEMBRANE SHORT COURSE

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RAVEN

OUTLINE, ESOS, 2016

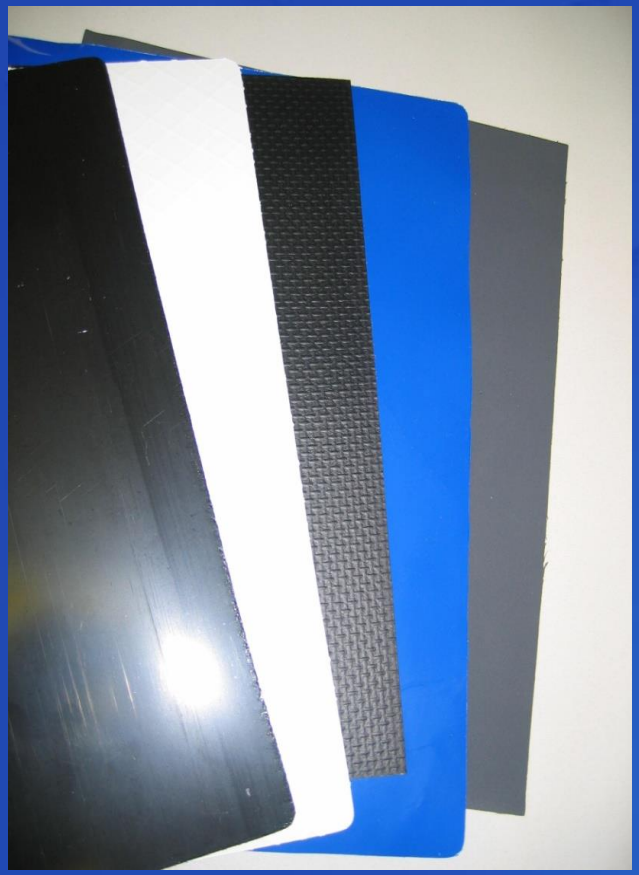
- Geomembrane Overview, Types
- Physical Properties, Test Biases
- Field Seam CQC / QCA
- Leak Location Testing
- Longevity and End of Life Prediction
- Summary

GEOMEMBRANE OVERVIEW

ASTM Definition of a **Geosynthetic Barrier**

- Geosynthetic Barrier (GBR), Low permeability geosynthetic material, used in geotechnical and civil engineering applications with the purpose of reducing or preventing the flow of fluid through the construction.

What is a **Geomembrane**?



- Proposed ASTM Definition.
- Polymeric Geosynthetic Barrier, GBR-P: Factory assembled structure of geosynthetic materials in the form of a sheet in which the barrier function is fulfilled by a polymer other than bitumen

FUNCTION - CONTAINMENT

Liner, Water or Waste

Cover, Odor Control

FUNCTION - EXCLUSION

Cover - Contamination

Brownfield - VOCs

GEOMEMBRANE TYPES

- Unreinforced
- Reinforced
- Smooth
- Textured (structured)
- Multi-Layer or Multi-Component

ENVIRONMENTAL CONDITIONS

EXPOSED

BURIED

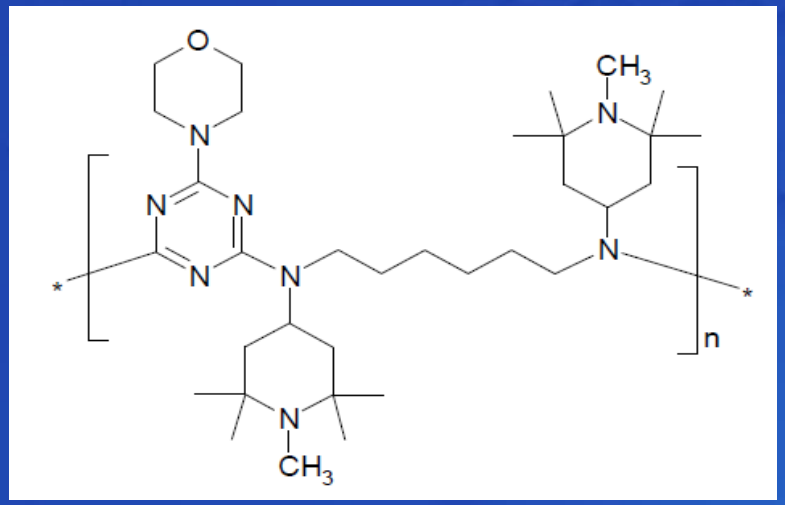
BASE POLYMERS

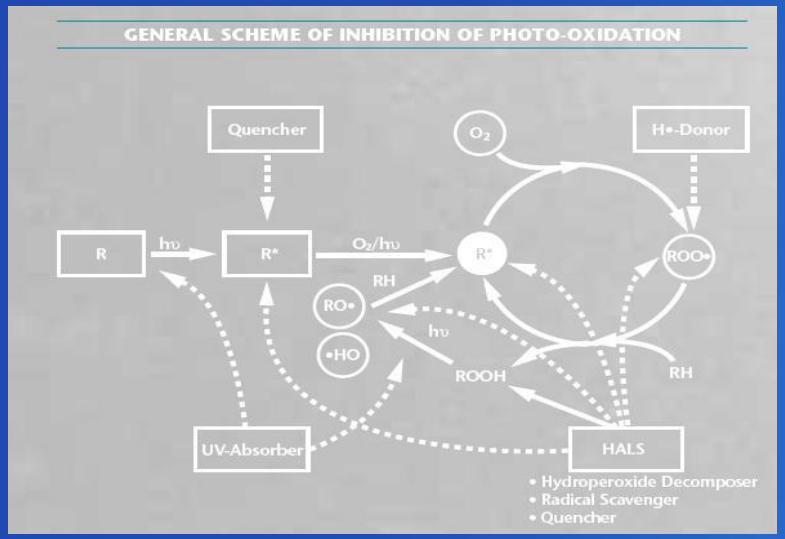
- PVC
- CSPE
- EPDM
- EIA
- EVOH
- Flexible PP (TPO)
- Polyethylene
- Polyurethane
- Polyester (PET)
- Polyamide (Nylon)
- Alloys, blends

PIGMENTS

- Aesthetics
- UV Resistance
- Temperature Control

STABILIZERS / MODIFIERS

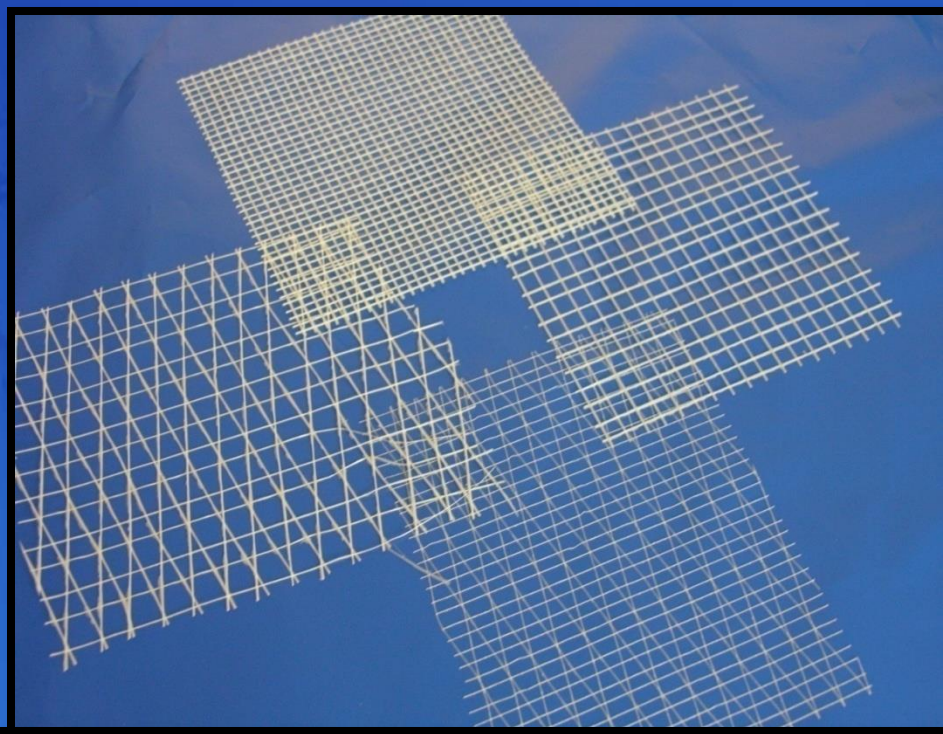


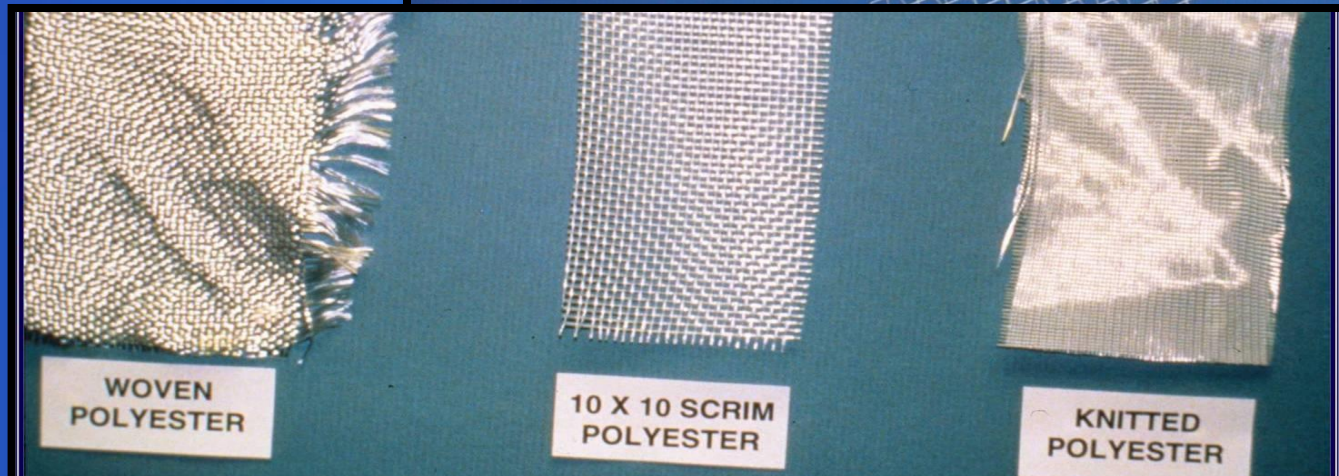


- Antioxidants
- Heat Stabilizers
- UV Stabilizers
- UV Absorbers
- Acid Scavengers
- Antimicrobials
- Plasticizers
- Fillers
- Polymeric modifiers

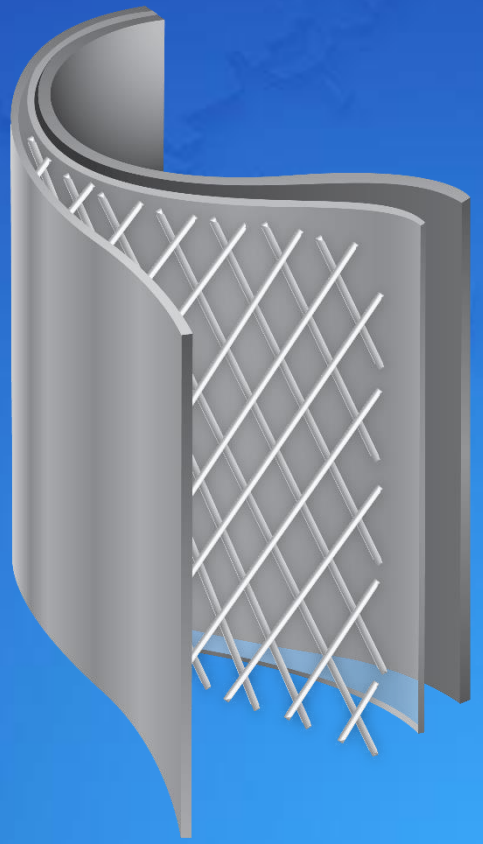
REINFORCEMENT

- Polymer Types
  - Polyester
  - Nylon
  - Polypropylene
  - Fiberglass
- Fibers
- Yarns
- Tapes

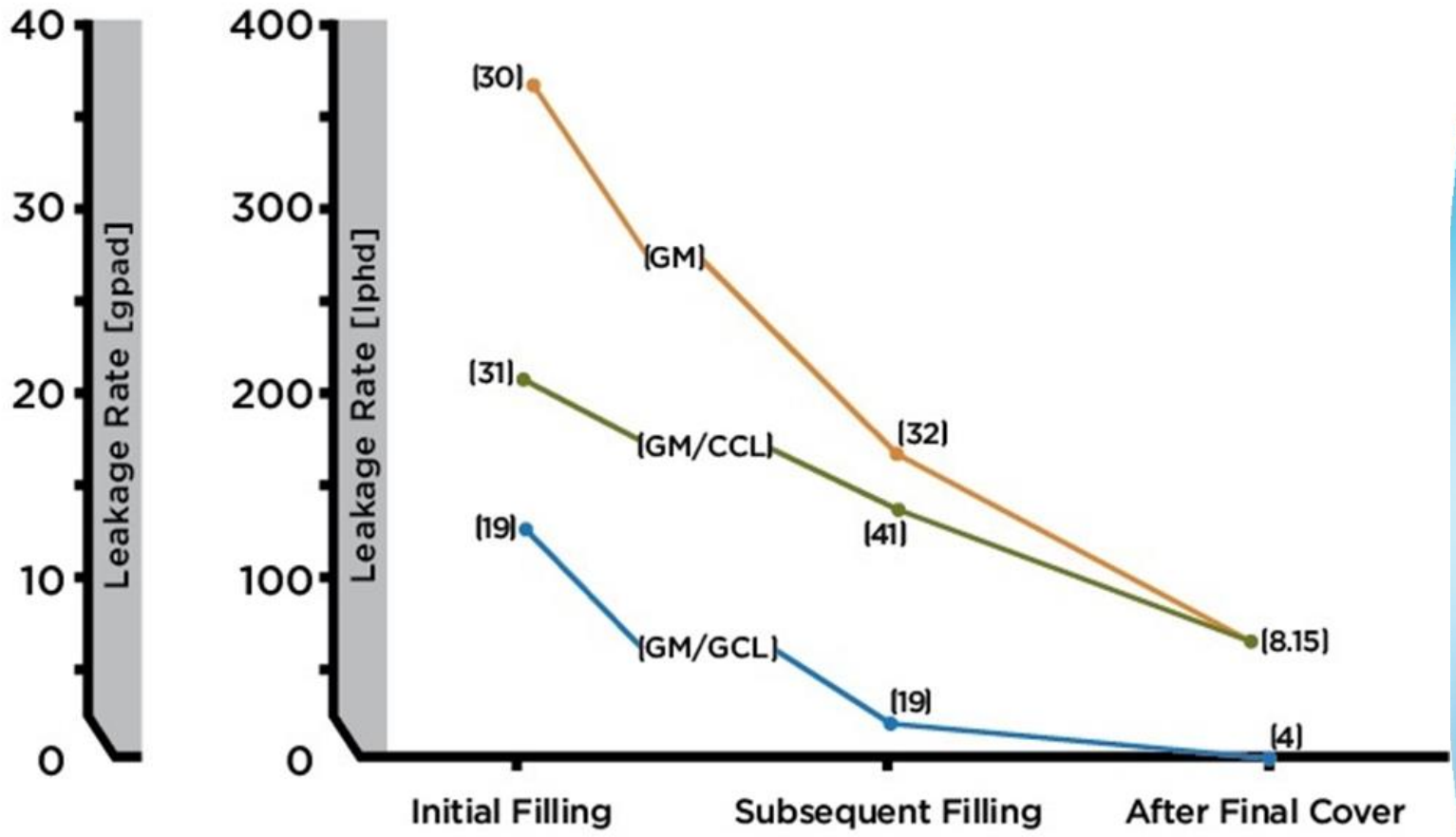




Reinforced GM Examples



LANDFILL LINER SYSTEM PERFORMANCE



[Ref: 2002 Bonaparte, Daniel and Koerner, U.S. EPA]

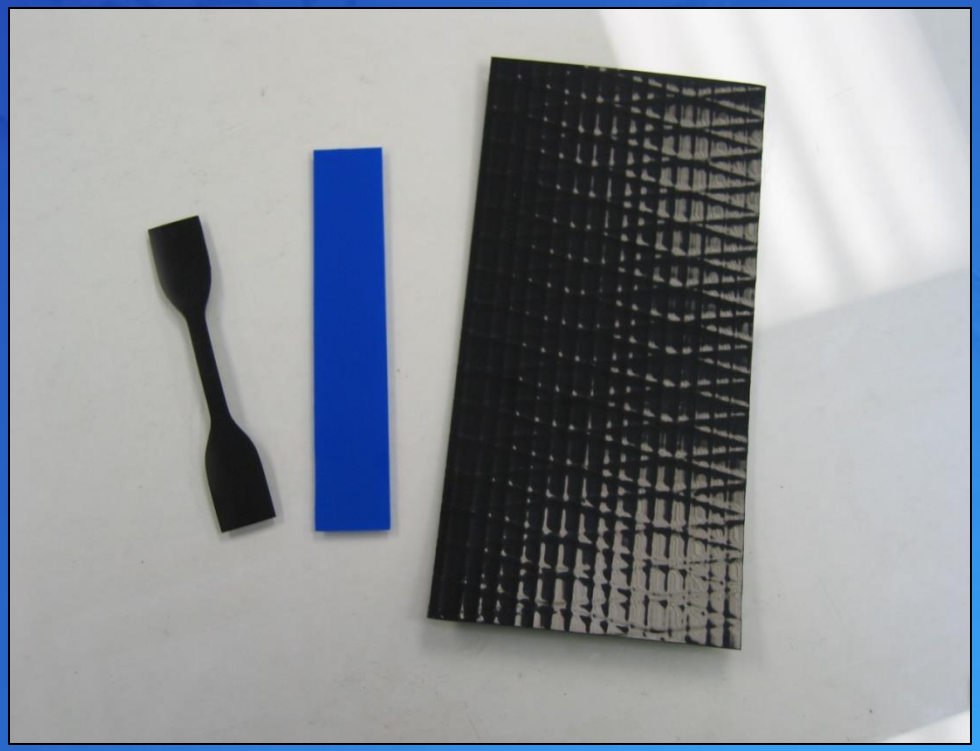
US EPA/600/R-02/099 Assessment & Recommendations for Improving the Performance of Waste Containment Systems

EXAMPLES, GEOMEMBRANE TEST PROCEDURES & BIASES

- D5199 vs D5994, Thickness smooth vs textured geomembranes

TENSILE PROPERTIES

- UNREINFORCED
  - D6693, dumbbell
  - D882, strip
- REINFORCED
  - D7003, strip
  - D7004, grab
- LARGE SCALE
  - D5617, multi-axial
  - D4885, wide width



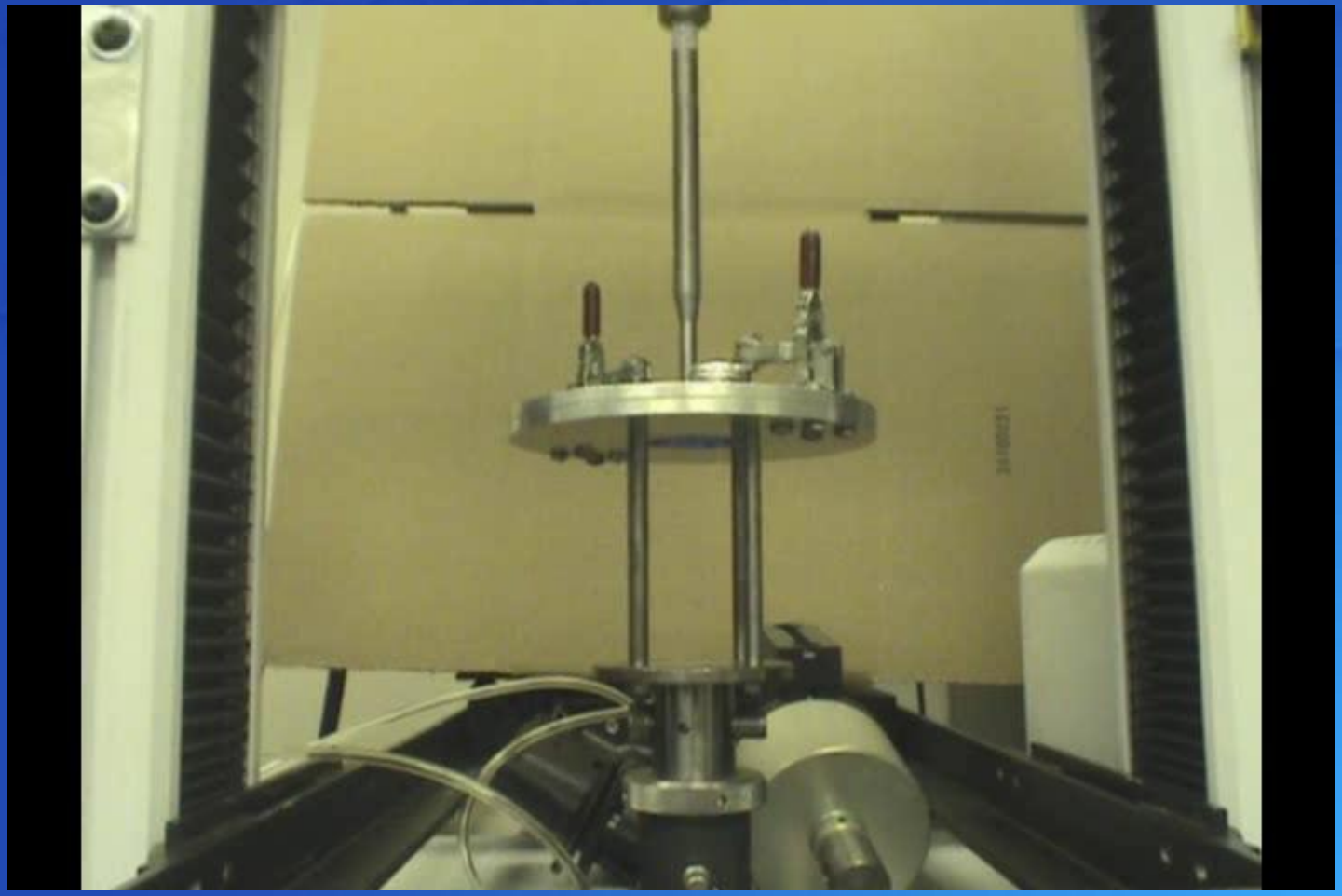
TENSILE ELONGATION

	HDPE	LLDPE
D6693 Dumbbell	800%	900%
D5617 Multi-axial	35%	85%

PUNCTURE RESISTANCE

- D4833, Index Puncture
- D6241, CBR
- D5494, Pyramid
- D5514, Large Scale Hydrostatic
- D1709, Impact Resistance, Dart

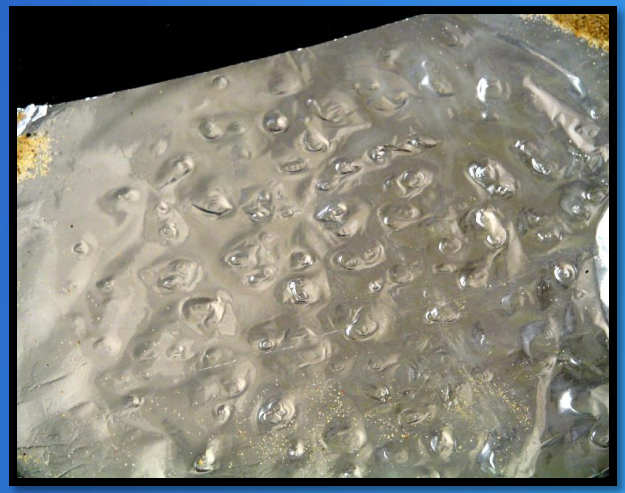
D4833 PUNTURE VIDEO



PUNCTURE RESISTANCE, STRAIN RATE EFFECT

	GM1	GM2
D4833 PUNCTURE	44 lb	46 lb
D1709 IMPACT	1400 g	3600 g

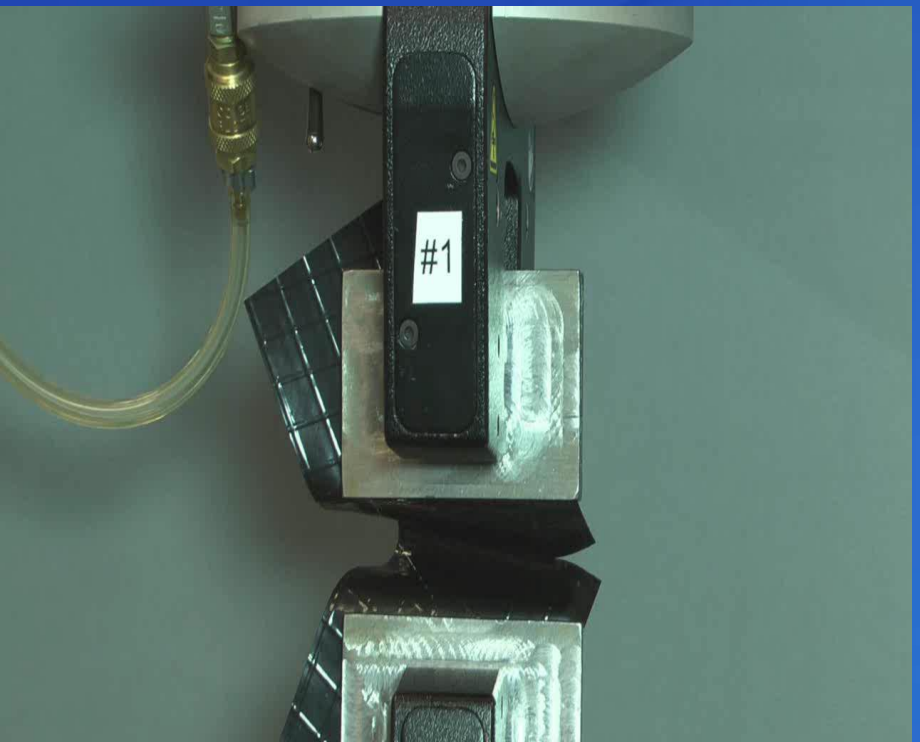
D5514, Large Scale Hydrostatic Puncture Resistance



TEAR RESISTANCE

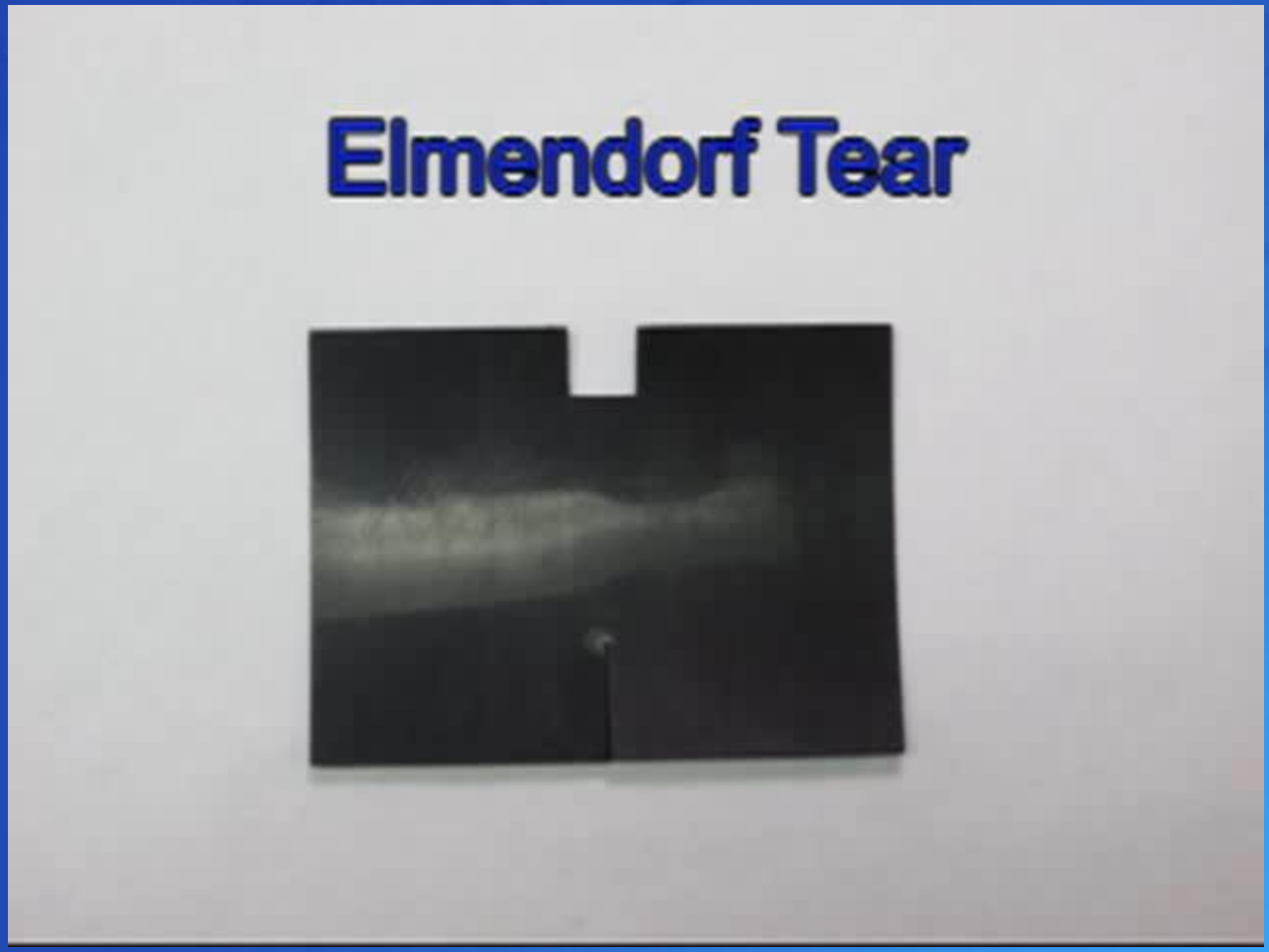
- REINFORCED
  - Tongue Tear, D5884
  - Trap. Tear, D4533
- UNREINFORCED
  - Graves Tear, D1004

TEAR TESTS

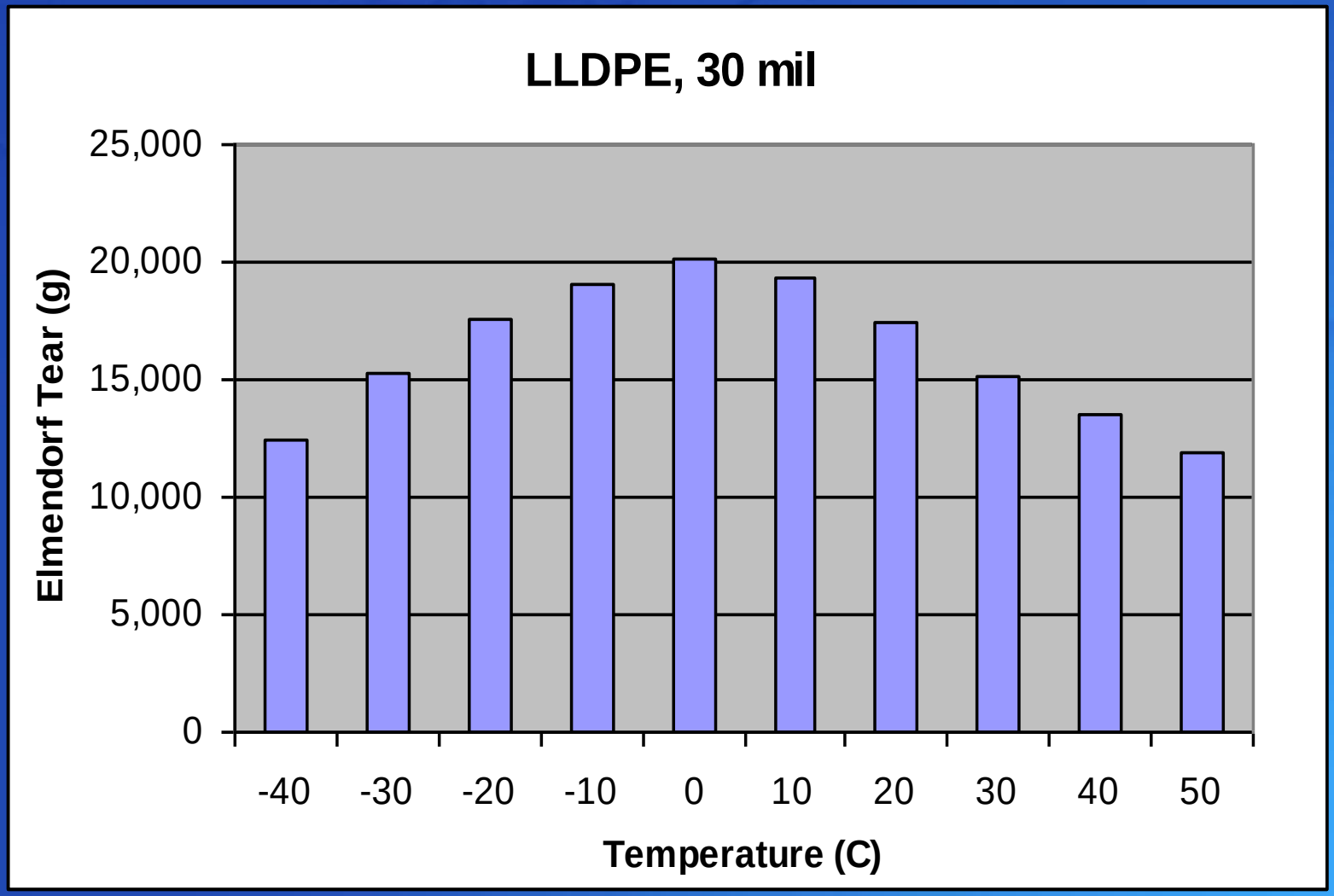


TEMPERATURE EFFECTS ON TEAR STRENGTH

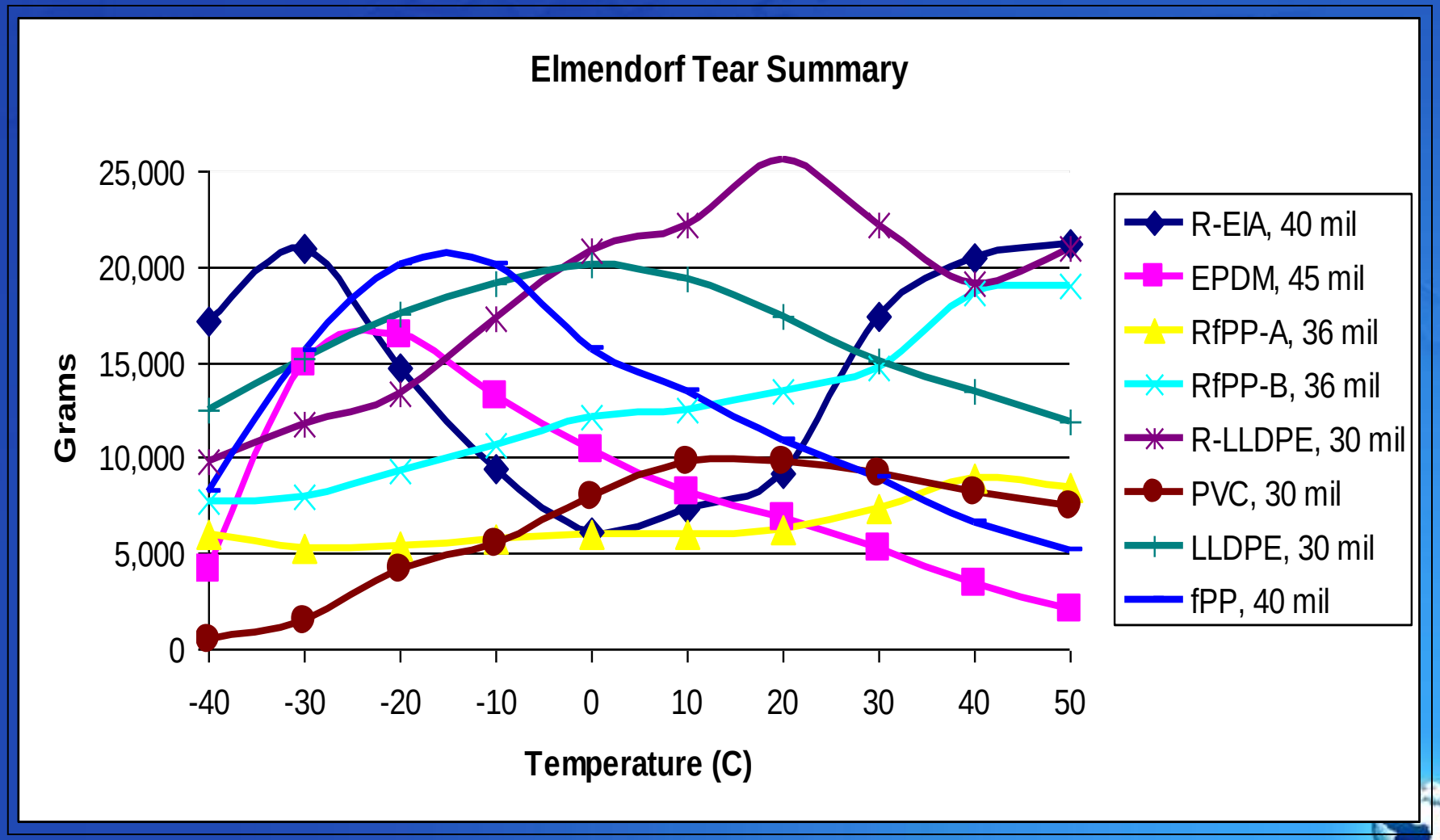
ELMENDORF TEAR



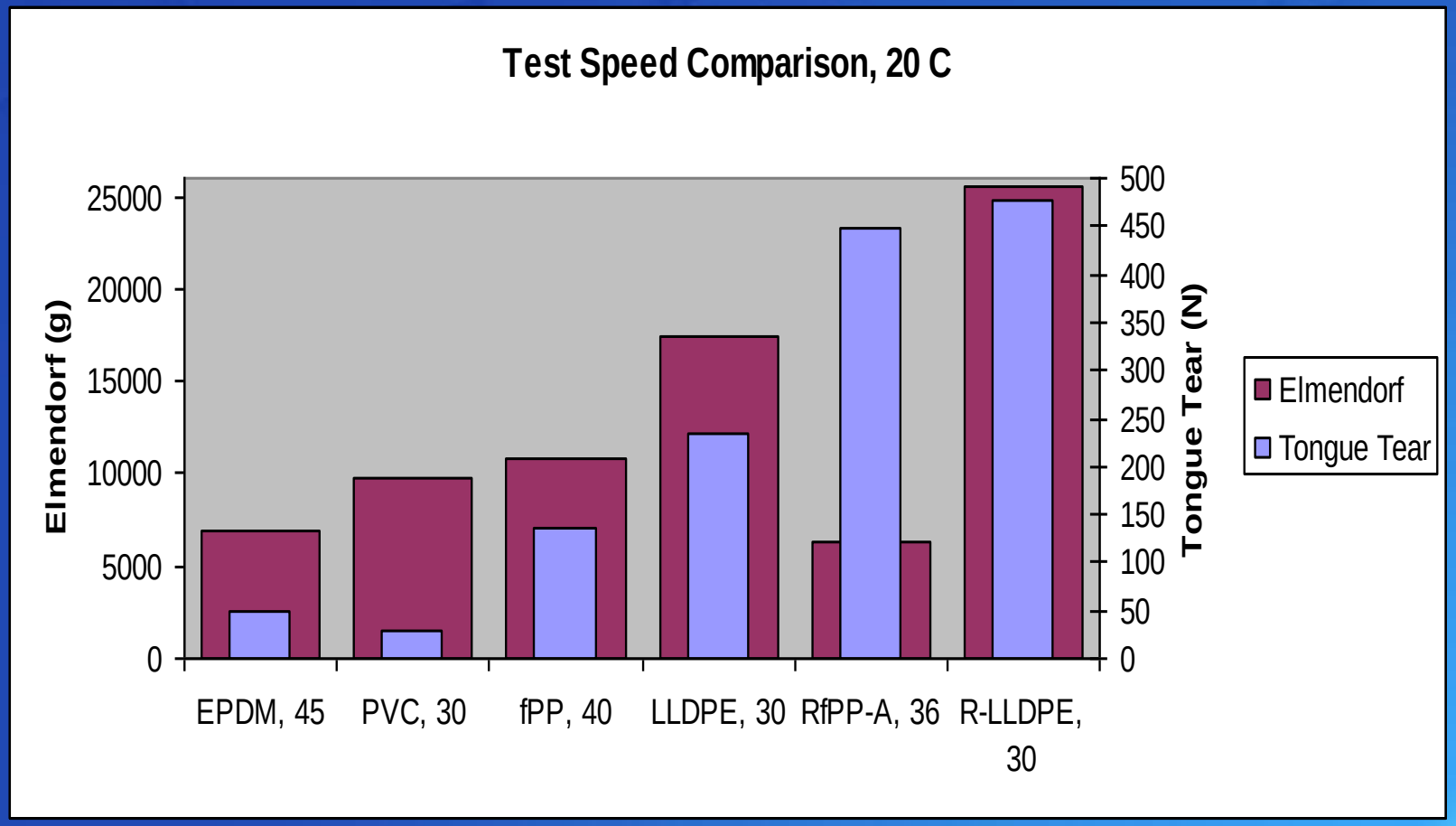
Tear vs Temperature, LLDPE



Tear Variation vs Temp.



Fast vs Slow Tear Tests



FIELD SEAM TESTING

SEAM TYPES

- Hot Wedge
- Extrusion
- Hot Air
- Chemical
- Glue
- Tape
- D7700, Guide for seam test methods

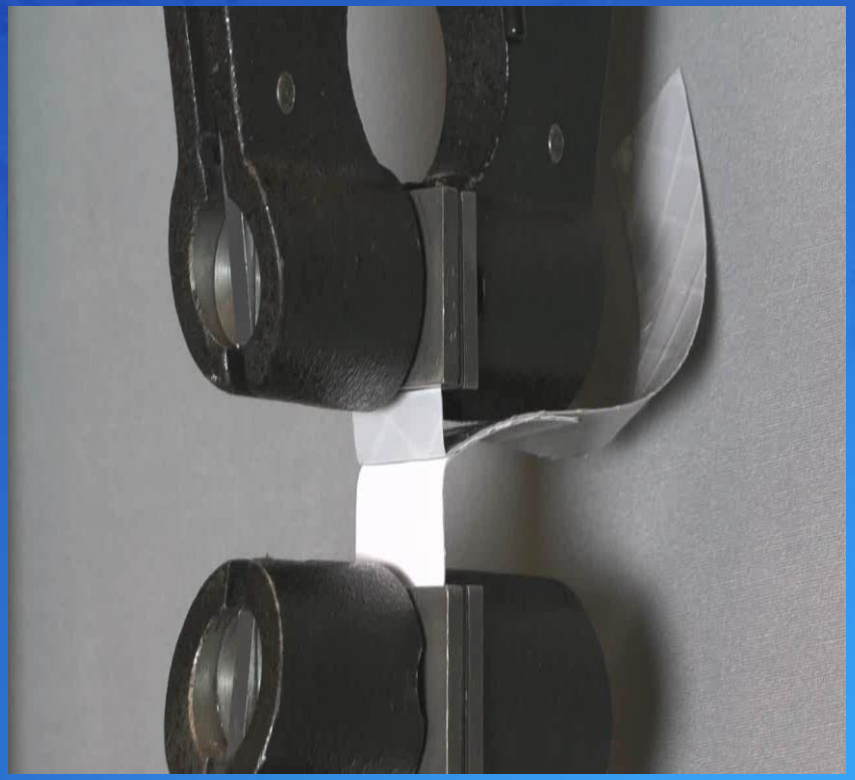
SEAM TESTS

- Destructive Test Methods
  - D6214, Chemical Fusion
  - D6392, Thermo-fusion
  - D7272, Taped
  - D7747, Reinforced Strip Method
  - D7749, Reinforced Seam Grab

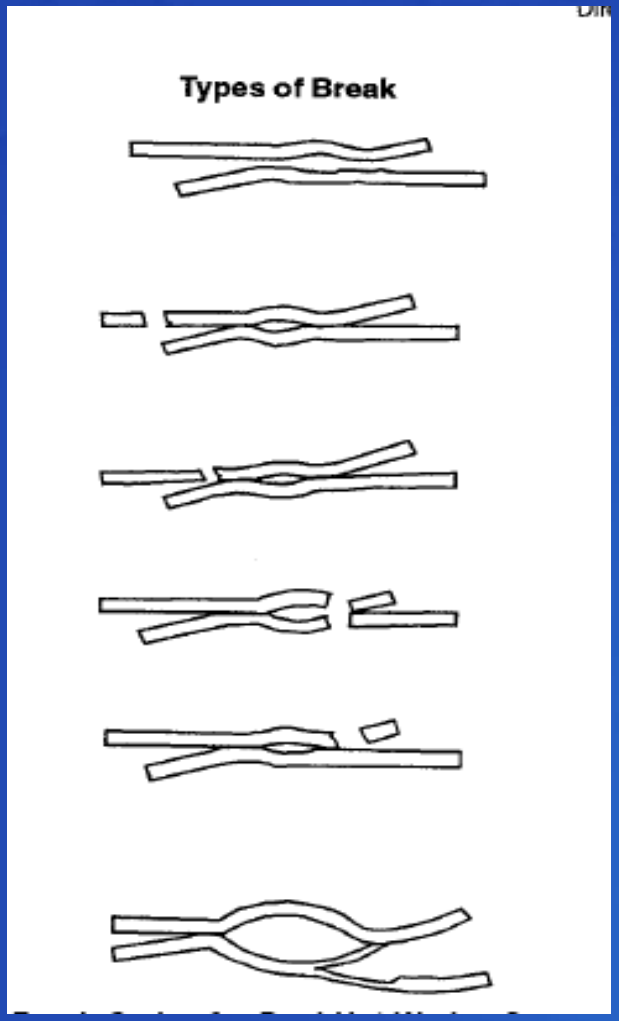
SEAM TESTS

- Non-Destructive Test Methods
  - D5820, Air Channel
  - D5641, Vacuum Chamber
  - D6365, Spark Test
  - D7177, PVC GM Air Channel
  - D4437, Non-Destructive

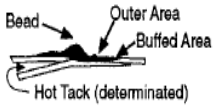
SEAM SHEAR SEAM PEEL

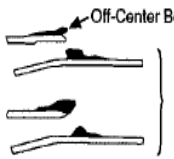


SEAM FAILURE MODES D6392

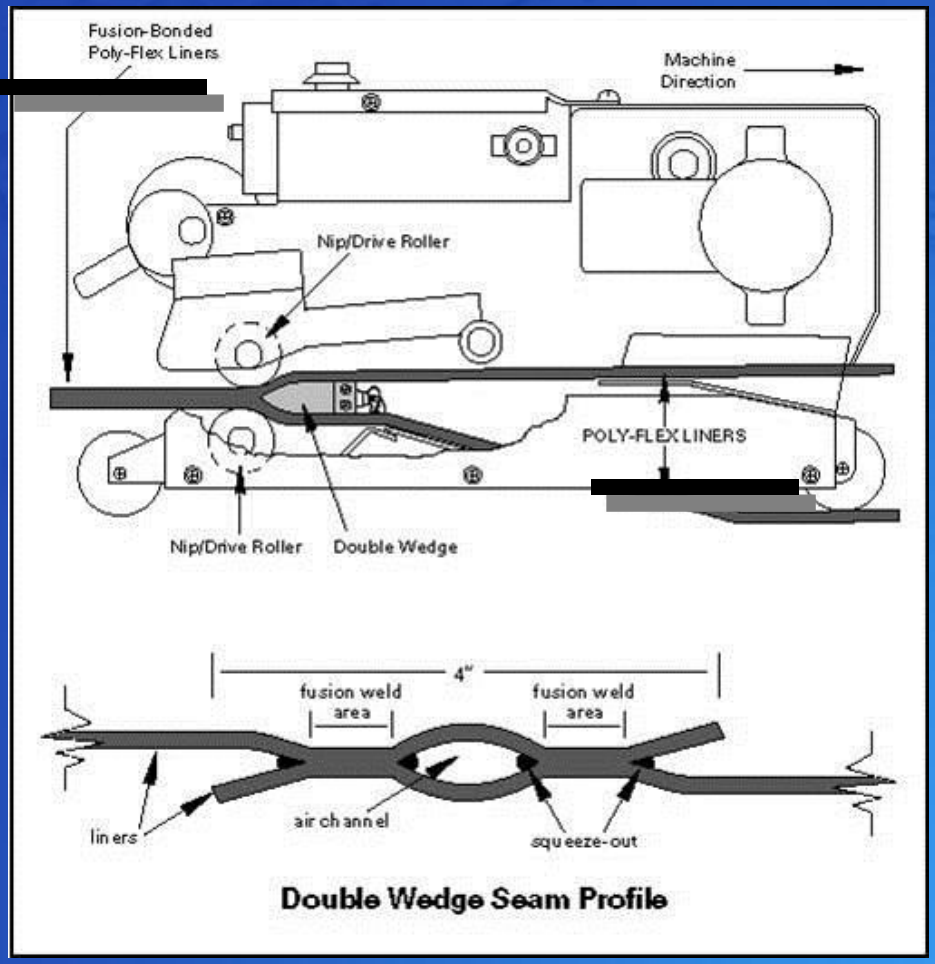


Schematic of Untested Specimen



Types of Break	Location of Break Code	Break Description
	AD1	Failure in adhesion. Specimens may also delaminate under the bead and break through the thin extruded material in the outer area.
	AD2	Failure in adhesion.
	AD-WLD[1]	Break through the fillet.
	SE1	Break at seam edge in the bottom sheet (applicable to shear only).
	SE2	Break at seam edge in the top sheet (applicable to shear only).
	SE3	Break at seam edge in the bottom sheet (applicable to peel only).
	BRK1	Break in the bottom sheeting. A "B" in parebtheses following the code means the specimen broke in the buffed area.

DOUBLE TRACK WEDGE WELD



D5820, AIR CHANNEL, HDPE

D7177, AIR CHANNEL, PVC

VACUUM BOX TESTING, D5641

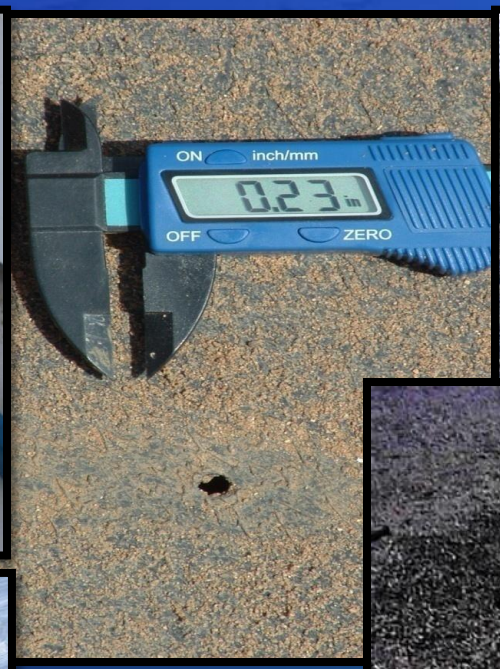
FACTORY SEAMS
FABRICATED GEOMEMBRANES

ASTM, FGI & IAGI Fabricated GM Guidelines

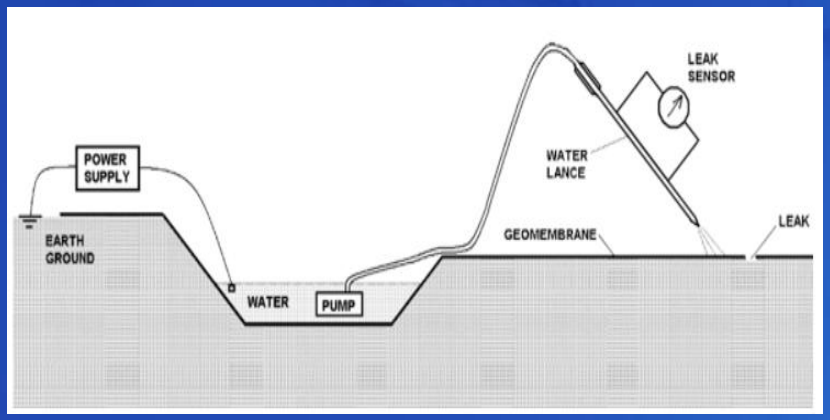
- D7865-13 Standard Guide for Identification, Packaging, Handling, Storage and Deployment of Fabricated Geomembrane Panels
- D7982-15 Standard Practice for Testing of Factory Thermo-Fusion Seams for Fabricated Geomembrane Panels
  FGI-4-2015: Guideline for Air Lance Testing of Field Geomembrane Seams
- Heavyweight Fabricated Geomembrane Guidelines
- Lightweight Fabricated Geomembrane Guidelines
- Compounded Fabricated Geomembrane Guidelines

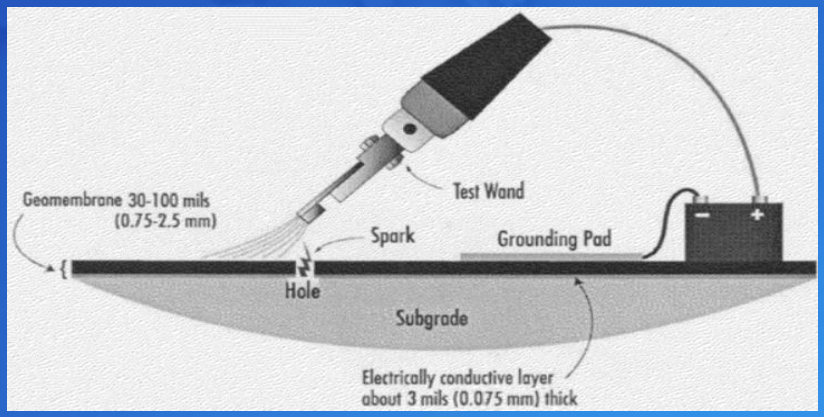
LEAK LOCATION TESTING, MAKING SURE IT WON'T LEAK

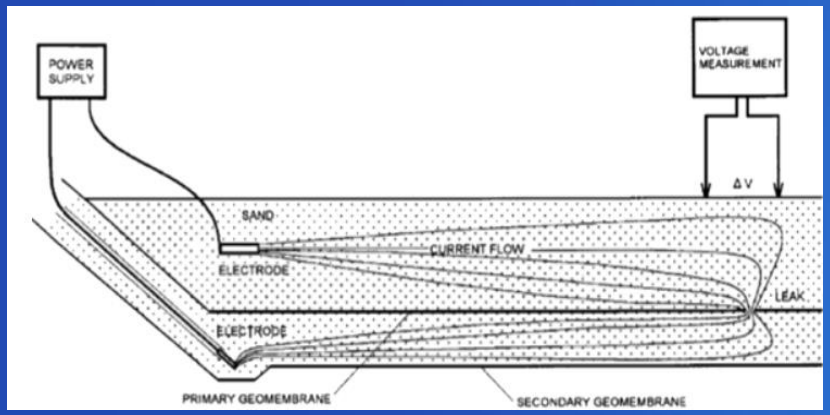
Examples of Leaks Found with Electric Leak Location Testing

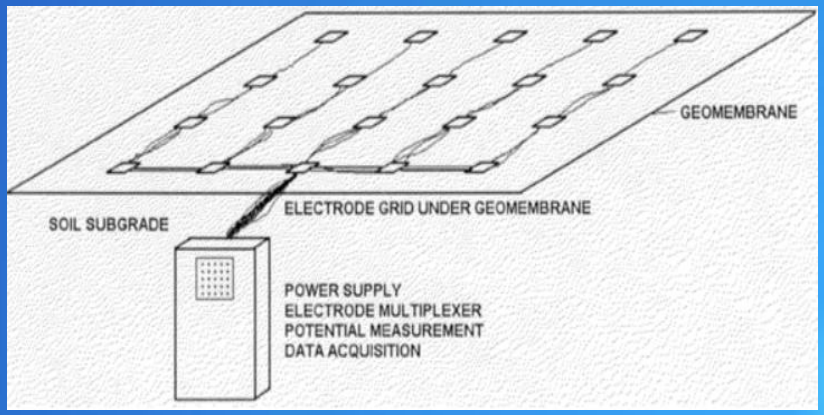


ASTM D6747, Selection of Techniques for Electrical Detection of Potential Leak Paths in Geomembranes







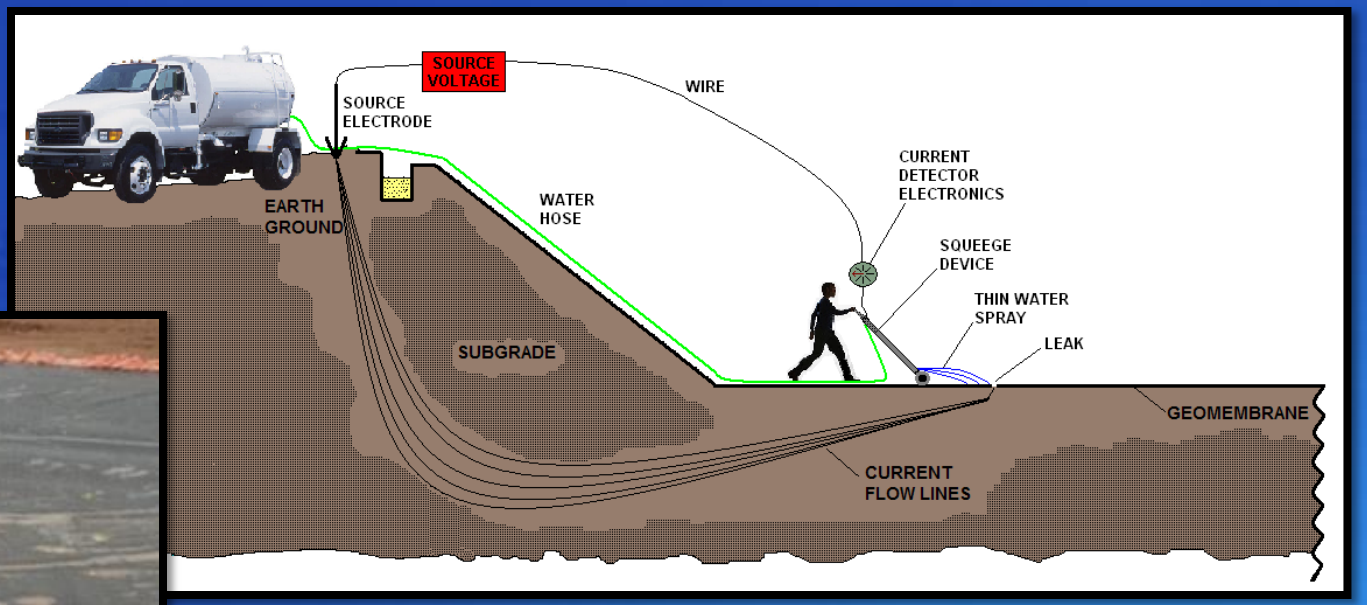


LINER LEAK LOCATION STANDARDS

- D7002, Puddle System
- D7703, Water Lance
- D7953, Arc Test
- D7240, Conductive GM Spark Test
- D7007, Water / Soil Covered GM
- D7852, Use of Conductive Geotextiles

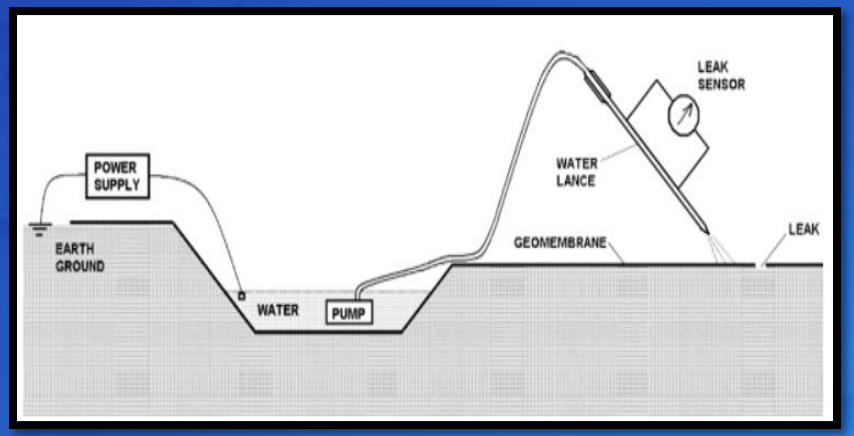
- D7909, Placement of Blind Leaks
- WK34962, Limitations With Different Techniques

D7002 PUDDLE METHOD



- Measures the current when a circuit is completed through a leak
- Squeegee creates a puddle from the streams.

D7703, Water Lance Method

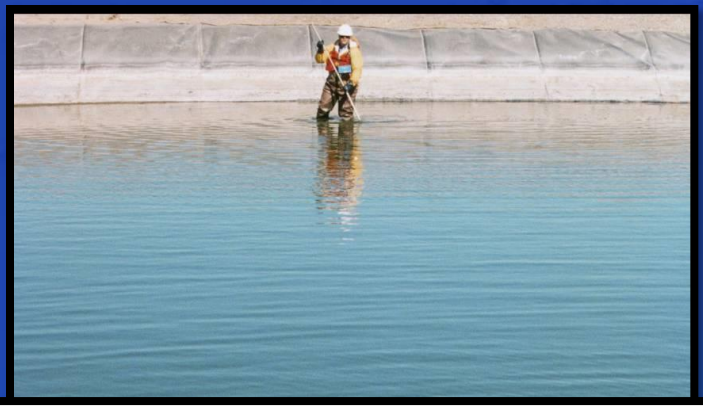


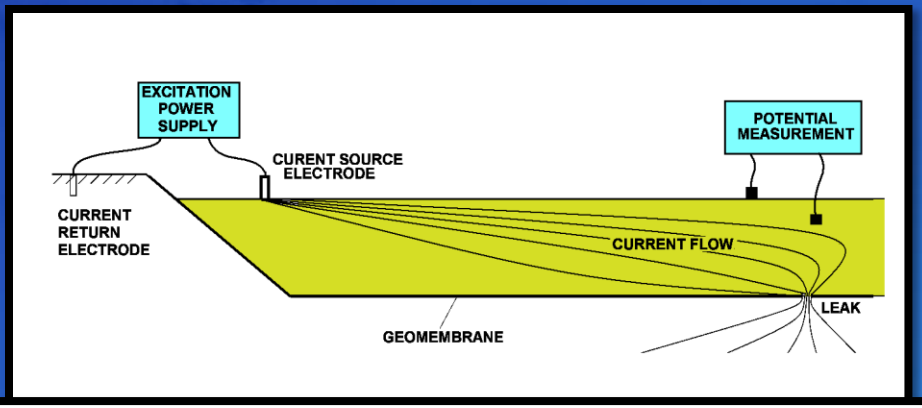
- Same as Puddle Method, Except no Squeegee.

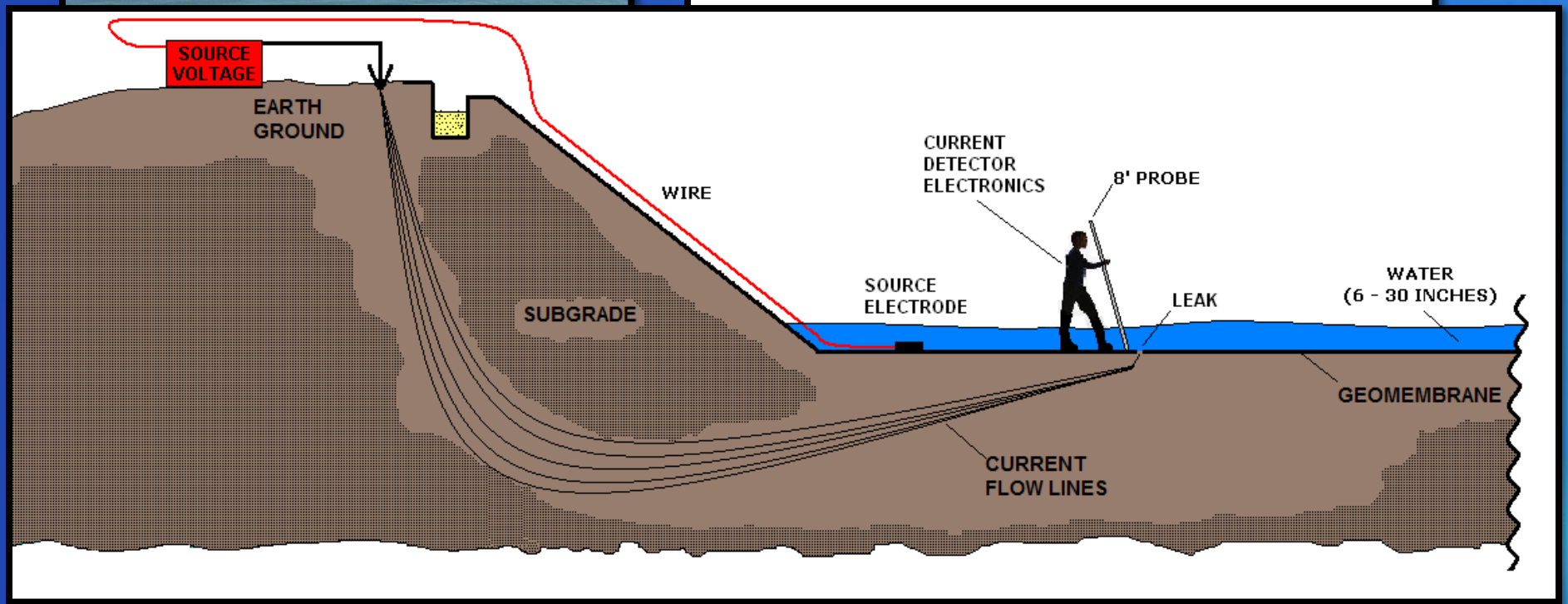
WATER LANCE AND PUDDLE

- FEATURES AND BENEFITS
  - Can be done during construction
  - Larger leaks do not mask smaller ones
  - ~500 sq. meters (5,000 sq. ft.) / hour, lance
  - >1,000 sq. meters (10,000 sq. ft.) / hour, puddle
  - Can detect leaks as small at 1 mm.
- LIMITATIONS
  - Can not be used on a covered geomembrane
  - Wrinkles do not contact soil, air insulator
  - Seam testing slow, needs time to penetrate

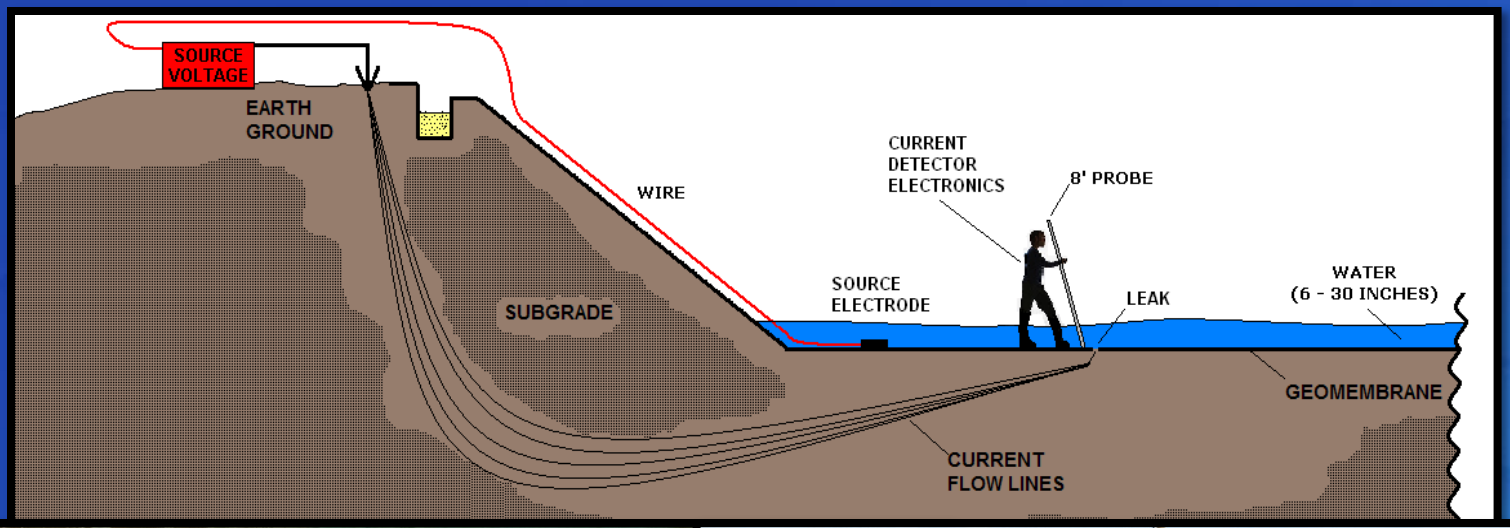
7007 WATER COVERED

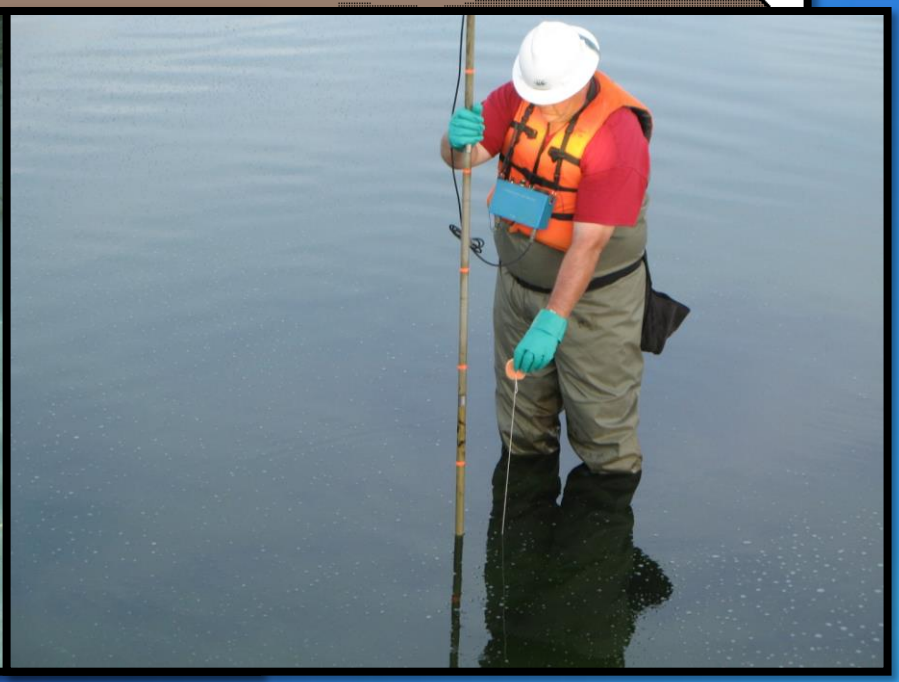






Water Covered, Marking Leaks



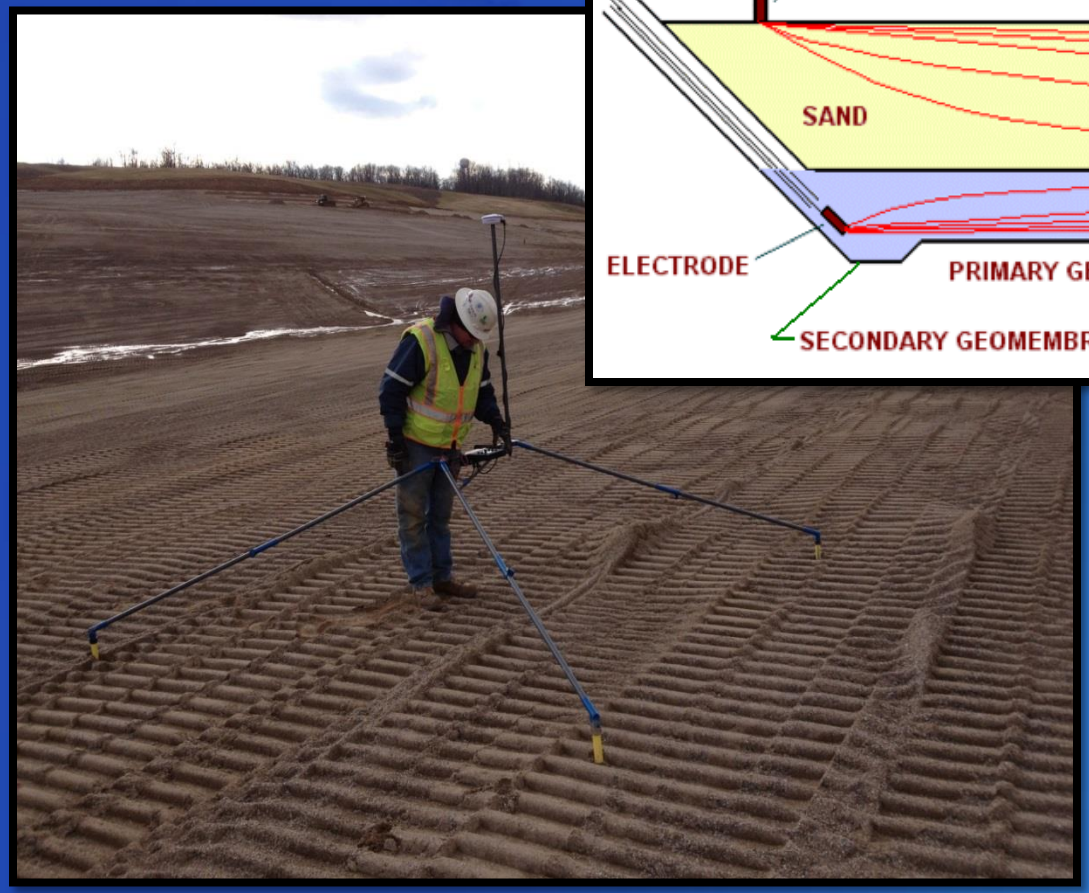


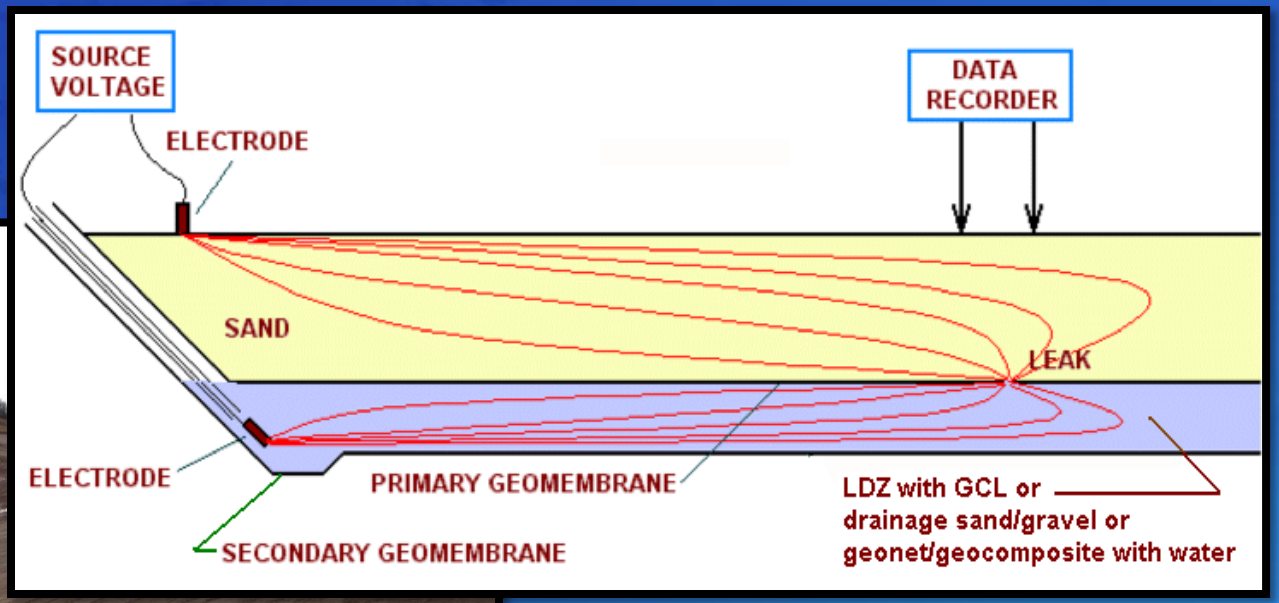
WATER COVERED

- FEATURES AND BENEFITS
  - Can test in-service ponds
  - Water head flattens wrinkles / penetrates leaks
  - Can find very small leaks, less than 1 mm.
  - ~1,000 sq. m (10,000 sq. ft.) / hr. per person.

- LIMITATIONS
  - Can not be done during construction
  - Large leaks may hide small leaks
  - A lot of water and time needed to fill and empty a deep pond

D7007, SOIL METHOD



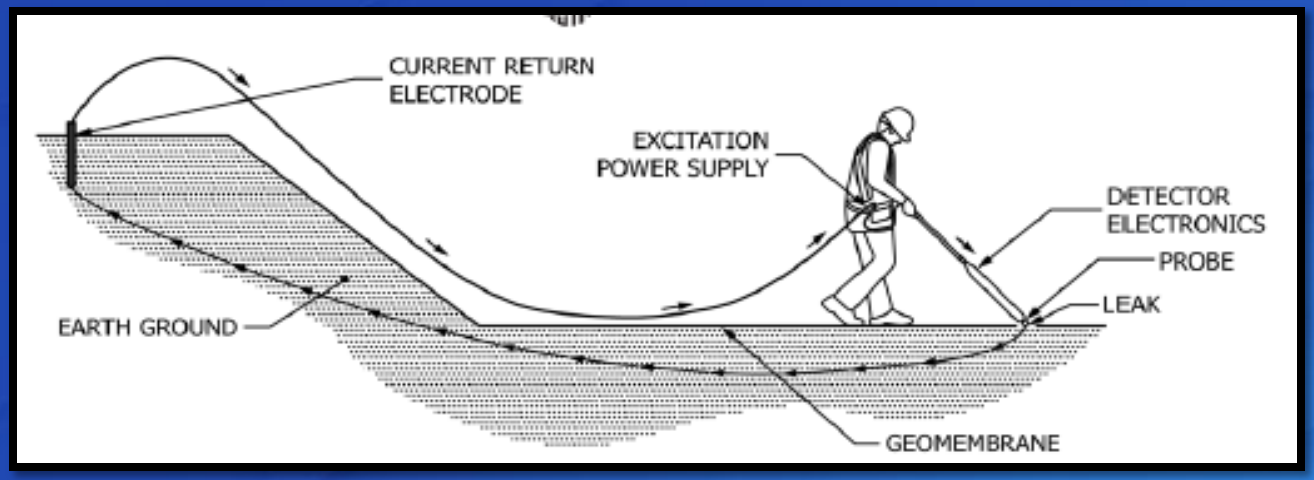


- Same principle as water covered method.

SOIL COVERED METHOD

- FEATURES AND BENEFITS
  - Detects leaks made during cover placement
  - ~400 to 1000 sq. m (4,000 to 10,000 sq. ft.) per hour per person
- LIMITATIONS
  - Cover soil must be wet
  - Large leaks may hide small leaks
  - Soil must be removed to repair leaks

D7953, Arc Leak Location Method



- High voltage arcs through the air and hole to the conductive layer beneath the GM.

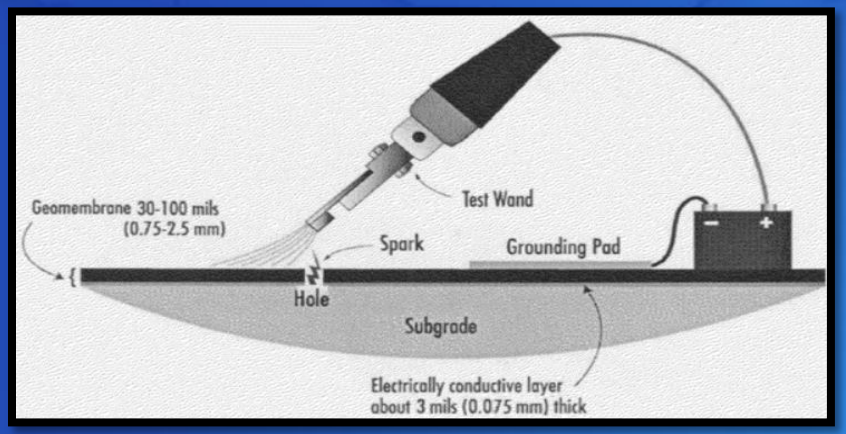
D7953, Arc Leak Location Method

- FEATURES AND BENEFITS
  - Can be done during installation
  - ~500 sq. m (5,000 sq. ft.) per hour per person
  - Can find pinhole sized leaks

- LIMITATIONS
  - Geomembrane must be clean and dry
  - Maximum air gap the spark can jump

What to do When There is Not a Conductive Layer Under the GM?

- D7240, Conductive Geomembrane

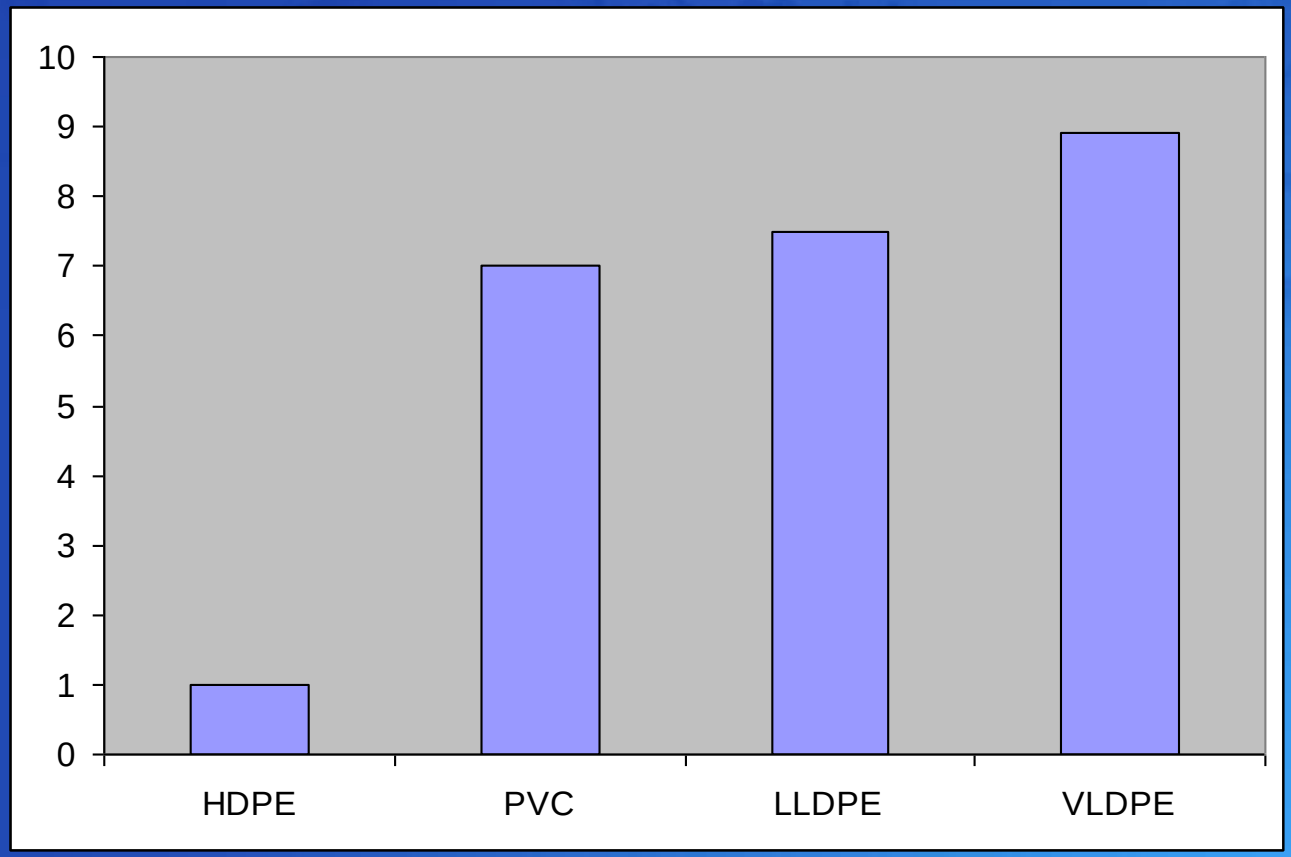


- D7853, Conductive Geotextile
- Place a conductive grid under the GM long term monitoring.

Electric Leak Location Survey Average Leaks per Hectare, HDPE

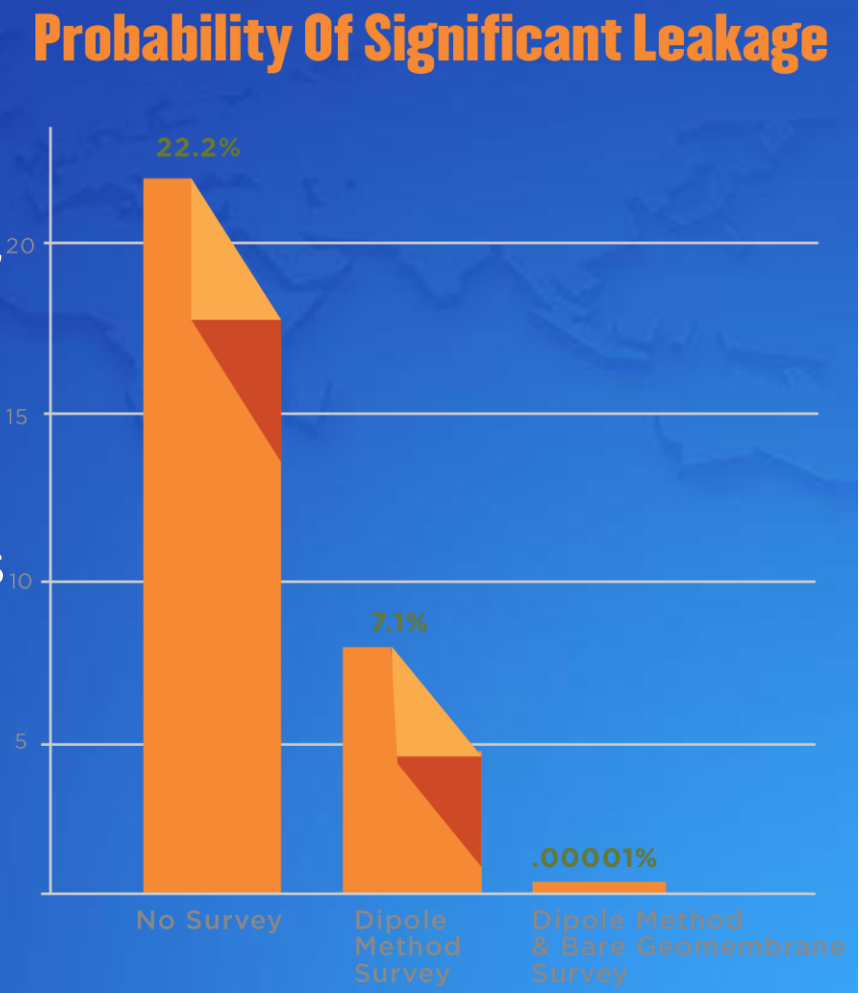
HDPE	No CQA	With CQA
80 mil	5.0	3.2
60 mil	7.5	5.1
40 mil	31.5	20.5

Critical Cone Height, cm



Leakage prevention and “Zero Leakage”

- A. Beck, "A Statistical Approach to Minimizing Landfill Leakage", SWANA, Washington D.C. Conference Proceedings, 2012.
- A. Beck, “ How Much Does my Landfill Leak?” Waste Advantage Magazine, December, 2012.



LEAK FREE STRATEGY

- CONSIDER PUNCTURE REQUIREMENTS IN GM SELECTION
- SUBGRADE PREPARATION CRITICAL
- ADEQUATE PUNCTURE PROTECTION
- USE CARE IN INSTALLATION
- USE AN EXPERIENCED CREW
- COVER PLACEMENT CRITICAL
- LEAK LOCATION SURVEY

LONGEVITY AND END-OF-LIFE (EOL) PREDICTION

DEFINITION: GEOMEMBRANE END OF LIFE

- **End of Life relates to the slow aging process and not catastrophic failure due to poor installation or a sudden application of external forces.**
- **End of Life, in most cases, is not when it fails**
- **End of Life (EoL) is when the geomembrane can no longer be relied on to perform its intended function.**

The Definition of EOL Depends on the Consequence of Failure, Severity of Impact

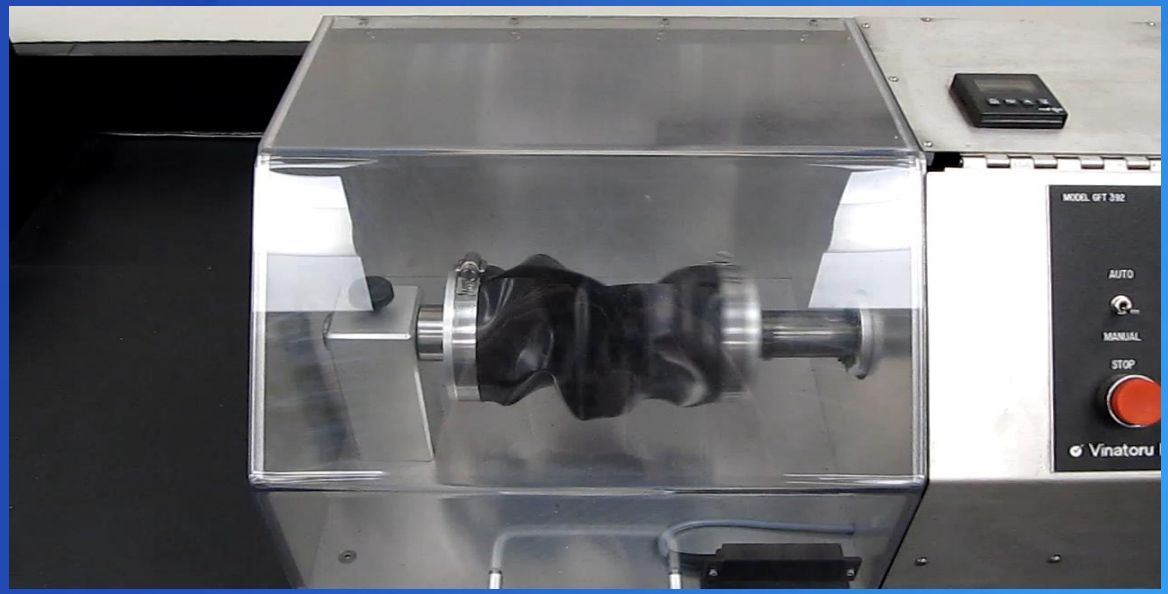
- Loss of Life
- Extensive Environmental Damage
- Economic Impact
- Impact on Operations

Need to Know Probable Mode Of Failure

- Considerations
- Application
- Stresses
  - Physical
  - Chemical
  - Energy
- Geomembrane Construction
  - Polymers
  - Additives
  - Multi-Component?

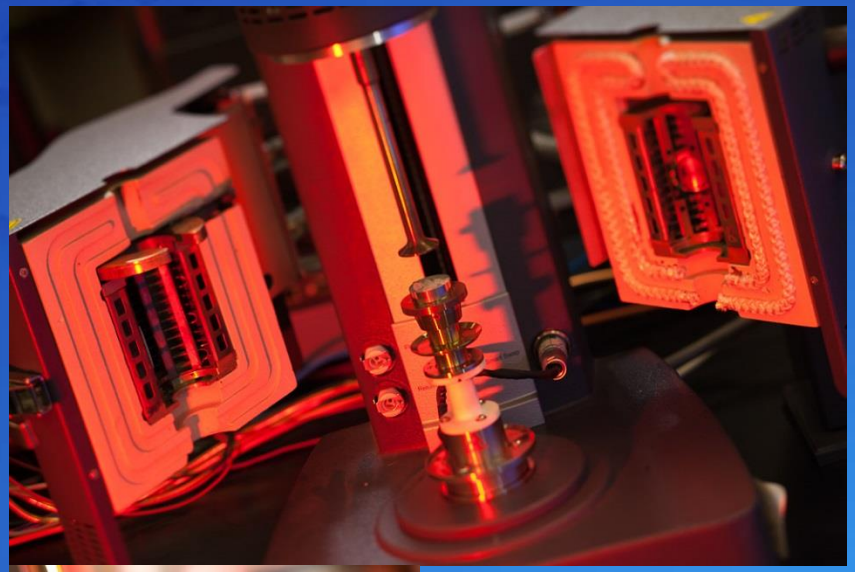
Tracking Expended Lifetime Involves More than Tracking One Test

- A Test for Condition of the Polymer
- A Test for the Condition of the Additives
- A Key Physical Property Test
- Multi-Layer May Need a Special Test



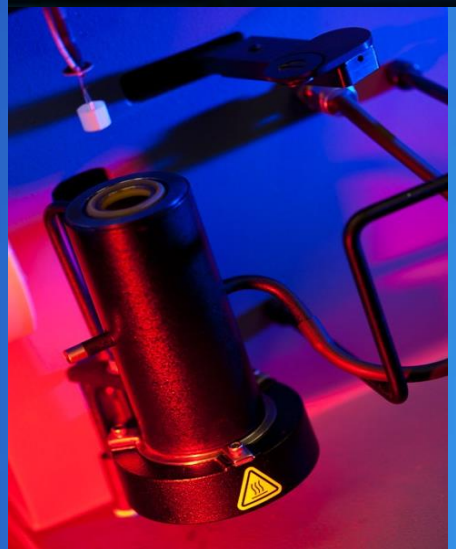
Polymer Tests (Polyethylene)

- Molecular Weight
  - Melt Index
  - Rheometery
  - Gel Permeation Chromatography
- Other Damage
  - Carbonyl Index



Additive Tests (Polyethylene)

- OIT
- HPOIT
- FTIR
- Extraction / Chromatography



Aging Tests

- UV
- Air Oven Aging
- Chemical Resistance
- Field Exposure

Other Items to be Aware Of: The Unexpected

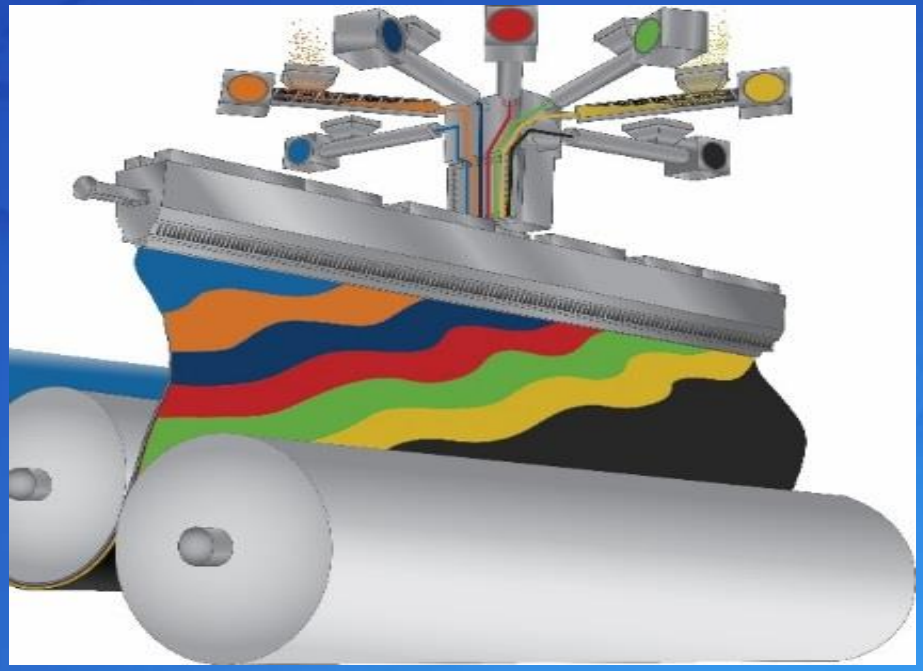
- Lifetime Can Be Improved by Synergistic Interactions.
- Performance Can Negatively Impacted by Antagonistic Interactions

Longevity / End of Life Summary

- The definition of EoL for a geomembrane is project specific
- Need to have a group of tests to monitor the health of the geomembrane
- Need to have the results interpreted, not just compared to a generic specification.

Multi-Layer Examples

- Black / White
- HD/LL/HD
- Conductive Surface
- PE/EVOH/PE
- Layered Stabilizers
- Aged Material



Multi-Layer Benefits

- Taylor surface layer performance.
- Get the synergistic effect of multiple materials
- Get performance not possible with single layer GMs

Multi-Layer Industry Activities

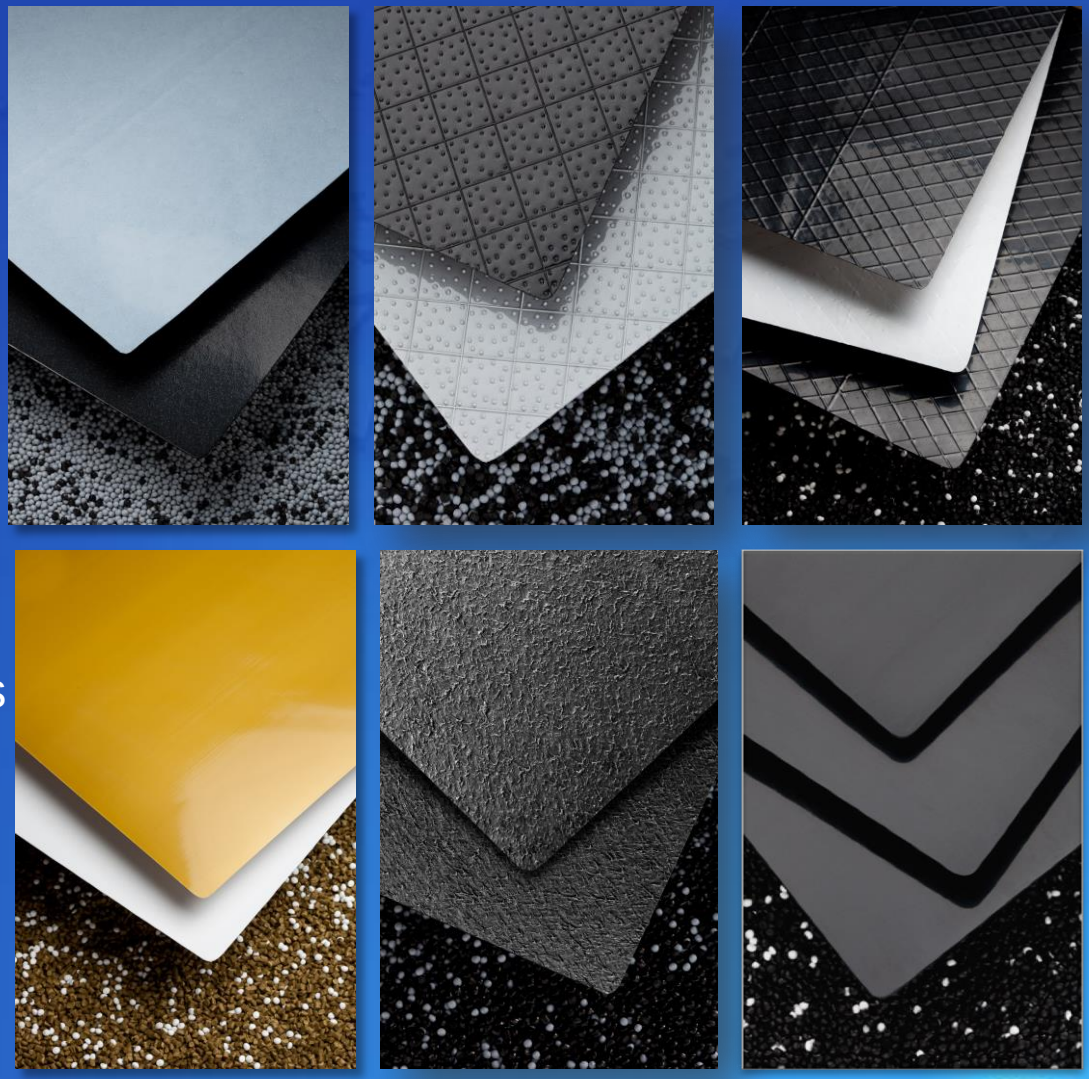
- ASTM
  - OIT, HPOIT
  - Carbon Black Content
  - NCTL (ESCR)
- GeoFrontiers 2017
  - Session on Multi-Layer Geomembranes

CLOSING COMMENTS

- Selecting And Specifying The Best Geomembrane For A Project Can Involve Many Performance Issues and Choices.
- This Presentation Did Not Cover All Of The Important Design Issues.

RavenEFD Products & Applications

- Product Types
  - Blown Film/Sheeting
  - Cast Film/Sheeting
  - Laminations/Coating
  - Textured Sheeting
- Applications
  - Industrial Packaging
  - Construction Films
  - Geo Liners & Covers
  - AG Covers & Liners
  - Energy Pit Liners
  - Building Systems



QUESTIONS?

RAVEN